

1 CLAIMS:

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3 Having thus described our invention, what we claim as
4 new and desire to secure by Letters Patent is as
5 follows:

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7 1. A method for depositing ruthenium on a substrate,
8 comprising:

9 exposing the substrate to a plasma which causes a
10 high concentration of nucleation sites to be formed on
11 the substrate, thus forming an exposed substrate; and

12 depositing ruthenium on the exposed substrate by
13 atomic layer deposition.

14

15 2. The method of claim 1, wherein the substrate is
16 selected from the group consisting of silicon dioxide,
17 methyl silsesquioxane, hydrogen silsesquioxane, other
18 low dielectric constant materials, and high dielectric
19 constant oxide substrates.

20

21 3. The method of claim 1, wherein said plasma is an
22 oxygen plasma.

23

24 4. The method of claim 3, wherein the oxygen plasma is
25 generated by passing molecular oxygen through a plasma
26 generation source to produce activated radicals to
27 thereby generate a large number of nucleation sites on
28 said substrate.

29

1 5. The method of claim 1, wherein said plasma is a
2 nitrogen plasma.

3

4 6. The method of claim 5, wherein the nitrogen plasma
5 is generated by passing molecular nitrogen through a
6 plasma generation source to produce activated radicals
7 to thereby generate a large number of nucleation sites
8 on said substrate.

9

10 7. The method of claim 1, wherein said atomic layer
11 deposition is performed by alternating steps of:

12 exposing the substrate to a ruthenium precursor
13 for a first predetermined period of time; and

14 exposing the substrate to a plasma for a second
15 predetermined time.

16

17 8. The method of claim 7, further comprising evacuating
18 the ruthenium precursor and the plasma between
19 successive steps.

20

21 9. The method of claim 8, wherein the evacuating is
22 done for a period of substantially two seconds.

23

24 10. The method of claim 7, wherein the ruthenium
25 precursor is selected from the group consisting of:
26 ruthenium cyclopentadienyl,
27 bis (ethylcyclopentadienyl) ruthenium; and
28 ((2,4-dimethylpentadienyl)ethylcyclopentadienyl) ruth-
29 enium).

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1 11. The method of claim 7, wherein the ruthenium
2 precursor is carried in a carrier gas.

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4 12. The method of claim 11, wherein the carrier gas is
5 argon.

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7 13. The method of claim 7, wherein said first
8 predetermined period of time is 4 seconds.

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10 14. The method of claim 7, wherein said second
11 predetermined period of time is 2 seconds.

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13 15. The method of claim 1, wherein said exposing of
14 said substrate to said plasma is performed for
15 substantially 10 minutes or longer.

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17 16. The method of claim 1, wherein said substrate is
18 heated to a temperature of between 200 and 400 °C.

19

20 17. The method of claim 1, wherein said substrate is
21 heated to a temperature of substantially 350 °C.

22

23 18. The method of claim 1, wherein said ruthenium is
24 deposited directly on said substrate without use of a
25 seed layer.

26

27 19. A method for depositing ruthenium on a substrate,
28 comprising:

29 performing plasma enhanced atomic layer deposition
30 of ruthenium on the substrate using a ruthenium

1 precursor and a plasma to form a thin film of
2 ruthenium; and

3 depositing ruthenium on the thin film by thermal
4 atomic layer deposition.

5

6 20. The method of claim 19, wherein said plasma is a
7 hydrogen plasma.

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9 21. The method of claim 19, wherein said atomic layer
10 deposition is performed by alternating steps of:

11 exposing the substrate to a ruthenium precursor
12 for a first predetermined period of time; and

13 exposing the substrate to a plasma for a second
14 predetermined time.

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16 22. The method of claim 21, further comprising
17 evacuating the ruthenium precursor and the plasma
18 between successive steps.

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20 23. The method of claim 22, wherein the evacuating is
21 done for a period of substantially two seconds.

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23 24. The method of claim 21, wherein the ruthenium
24 precursor is selected from the group consisting of:

25 ruthenium cyclopentadienyl,

26 bis (ethylcyclopentadienyl) ruthenium; and

27 ((2,4-dimethylpentadienyl)ethylcyclopentadienyl) ruth-
28 enium).

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1 25. The method of claim 21, wherein the ruthenium
2 precursor is carried in a carrier gas.

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4 26. The method of claim 25, wherein the carrier gas is
5 argon.

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7 27. The method of claim 21, wherein said first
8 predetermined period of time is 4 seconds.

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10 28. The method of claim 21, wherein said second
11 predetermined period of time is 2 seconds.

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13 29. The method of claim 19, wherein said substrate is
14 heated to a temperature of between 200 and 400 °C.

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16 30. The method of claim 19, wherein said substrate is
17 heated to a temperature of substantially 350 °C.

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20 31. A ruthenium film formed by atomic layer deposition
21 comprising less than three percent oxygen and less than
22 2 % carbon.

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24 32. The ruthenium film of claim 31, configured as a
25 gate of a CMOS device.

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27 33. The ruthenium film of claim 31, deposited on a
28 silicon dioxide substrate.

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1 34. The ruthenium film of claim 31, deposited directly
2 on a substrate without use of a seed layer.

3

4 35. The ruthenium film of claim 31, for serving as a
5 plating layer for a copper interconnect.